Relationship between diversity of forest plant species and environmental gradient in eastern mountainous area of Heilongjiang Province, China

WANG Qing-gui[1,2], XING Ya-juan [2], ZHOU Xiao-feng[3], HAN Shi-jie[1]

[1] *Institute of Applied Ecology, Chinese Academy of Sciences, Shenyang 110016, P.R. China*

[2] *Heilongjiang University, Harbin 150080, P.R. China*

[3] *Northeast Forestry University, Harbin 150040, P.R. China*

Abstract: Twenty-three secondary forest communities with different structure were selected in Mao'er Mountain National Park of Heilongjiang Province, China to study the relationship between diversity of forest plant species and environmental gradient. The forest plant species diversity was analyzed by the diversity index, and the environmental factors was quantified by the method of Whittaker's quantification of environmental gradient. Meanwhile, β-diversity indexes of communities were calculated with similar measurements. The results showed that the Shannon-wiener diversity index of forest plant species increased with the increase of the environmental gradient, and the β-diversity indexes of communities showed a liner increase along with the change of environmental gradient.

Key words: Species diversity; Forest plant species; Heilongjiang Province; Shannon-wiener diversity; β-diversity index; Environmental gradient

CLC number: S718.55 **Document code:** A **Article ID:** 1007-662X(2006)03-0252-03

Introduction

The distribution of species diversity is neither random nor even, which is closely related to environmental factors and biological influence (Wang 2006). Biogeographers and ecologists had noticed that one region not only had different species with another one, but also had different composition of plant or animal obviously. Biodiversity is often defined as the variety of all forms of life, from genes to species, through to the broad scale of ecosystems (Gaston 1996).

Some early studies showed that the pattern of biodiversity might be set up in different scale and environmental gradient, and many researchers recognized that single factor of environment was important for the biodiversity establishment (Wang 2006). Biogeographers noticed that the number of species decreased from equator to pole (Brown *et al*. 1983; Currie *et al*. 1987), which means the species diversity increased with the increase of annual average temperature (decreasing of latitude gradient) in earth. The relationship between species diversity and altitude was very complex, and the dynamics of variation between species diversity and altitude was similar to that of latitude gradient, but people always found that pattern of biodiversity was changeable with different latitudes, exposures, altitudes, and different species (Kikkawa *et al*. 1971; Terborg 1977).

This paper takes the temperature, soil moisture, soil depth, and altitude as an environmental gradient composition (Whittaker 1960) to quantify environmental gradient and reveal relationship between diversity of forest plant species and environmental gradient in eastern mountainous area of Heilongjiang Province, China.

Foundation project: The paper was supported by National Natural Science Foundation of China (39899370).

Biography: WANG Qing-gui (1970-), male, Ph.D., associate professor of Heilongjiang University, postdoctor in Institute of Applied Ecology Chinese Academy of Sciences. E-mail: qgwang1970@163.com.

Received date: 2005-12-30

Accepted date: 2006-01-16

Responsible editor: Song Funan

Quantification of environmental gradient

Environmental gradient is expressed by *Gc* (Gradient composition), and *Gc* is the composition of *Gt* (Temperature gradient), *Gw* (Water gradient), and *Gs* (Soil fertilizer gradient) (Whittaker 1960). So, Gc can be calculated as follows:

$$Gc=1/3 \times (Gt+ Gw+ Gs) \tag{1}$$

The first, *Gt* can be calculated as follows:

$$Gt=(Hx-Hl)/(Hr-Hl) \tag{2}$$

where, *Hr* is the highest altitude of research region (m), *H*l the lowest altitude of research region (m), and *Hx* is the altitude of community (m).

The second, *Gw* is influenced by the slope exposure, which can be divided into 8 grades. If one community lives in one slope exposure, the *Gw* is the moistest when the slope faces to the north and the number of quantification is 8; and the Gw is the driest when the slope faces to the south, the number of quantification is 1. The number of quantification of *Gw* at each slope exposure are listed in Table 1.

The third, *Gs* can be calculated by soil depth and soil moisture. Soil depth was divided into 10 grades, <10 cm, 10–20 cm, 20–30 cm … > 90 cm. Soil moisture was divided into 5 grades, <10%, 10%–15%, 15%–20%, 20%–25%, 25%–30%. According to the above approaches, we can calculate the values of environmental gradient.

Methods

Data collection

The research site was located in Mao'er Mountain National Park (127°30′E–127°34, 45°20′–45°25′N) of Northeast Forestry University, China. Twenty-three secondary forest communities with different structure were selected. In each plot (20 m×20 m),

the number of species, the number of individuals, grass coverage, height of trees, altitude of plot, slope gradient, exposure, slope position, soil depth, and soil moisture were investigated.

Data analysis

The diversity index is calculated by Shannon-wiener's measure *H'* (Magurran 1988). And the *H'* is calculated as follows:

$$H' = \sum P_i \ln p_i \qquad (3)$$

where, *H'* is Shannon-wiener's diversity index, P_i is proportion of individuals in the *i*th species.

β-diversity is calculated by the following equation:

$$CN = \frac{2\,jN}{aN + bN} \qquad (4)$$

where, *CN* is β-diversity index, *aN* the number of individuals in plot a, *bN* the number of individuals in plot b, *jN* is the number of existence together in plot a and plot b.

Table 1. The number of water gradient of every slope exposure

	Grades of water gradient							
	1	2	3	4	5	6	7	8
Slope exposure	South	Westsouth	Southeast	West	East	Northwest	Northeast	North
Azimuth compass	157.5°–202.5°	202.5°-247.5°	112.5°-157.5°	247.5°-292.5°	67.5°-112.5°	292.5°-337.5°	22.5°-67.5°	337.5°-360° 0°-22.5°

Results

Species diversity and environmental gradient

Species diversity and environmental gradient are given in Table 2. The values of quantification of altitude, exposure, slope, slope position, and soil moisture of 23 communities are calculated and listed in Table 2. The environmental gradient compositions of 23 communities were calculated by Whittaker's method, and the diversity index of every community was calculated by Shannon-wiener's measure. It can be found from Table 2 and Fig.1 that species diversity increases along with the increase of environmental gradient, but the correlation is not liner. Competition in plant species is relatively not severer in good condition community, more species can be held in, and thus species diversity is high.

Table 2. Species diversity index and quantification of environmental gradient of forest communities

Sequence of community	Altitude	Exposure	Slope	Slope position	Slope depth	Soil moisture	Environmental gradient composition	H'
1	8.17	2.78	22	0.47	7.99	7.44	6.22	3.06
2	9.27	4.78	25	0.79	8.20	4.86	6.86	3.05
3	8.72	4.02	15	0.86	7.60	10.0	7.18	3.50
4	8.90	1.40	35	0.91	9.99	6.52	6.19	3.68
5	1.38	7.39	40	0.19	9.60	10.0	6.19	3.66
6	2.48	6.85	35	0.33	7.50	10.0	6.03	3.25
7	3.39	2.84	45	0.46	4.10	9.90	4.26	1.77
8	3.76	2.56	15	0.51	8.20	10.0	5.14	3.35
9	4.86	1.59	15	0.65	7.50	10.0	5.07	3.13
10	5.23	3.37	15	0.70	8.10	10.0	5.88	3.27
11	5.78	2.50	10	0.78	4.82	4.62	4.33	3.30
12	6.15	2.39	10	0.80	4.55	2.31	3.99	3.27
13	6.51	1.31	30	0.65	5.50	9.62	5.13	3.12
14	6.51	4.41	30	0.65	6.30	8.56	6.12	2.65
15	7.61	1.30	10	0.91	9.99	8.79	6.10	3.52
16	5.78	2.54	35	0.50	4.90	10.0	5.22	2.91
17	4.31	3.17	17	0.21	5.85	5.45	4.54	2.86
18	3.58	5.59	20	0.07	7.80	10.0	6.02	2.50
19	3.58	1.81	10	0.07	6.80	8.95	4.32	2.28
20	6.88	3.61	25	0.74	5.13	4.33	5.07	3.28
21	6.88	3.61	25	0.74	5.13	4.33	5.07	3.10
22	6.70	2.39	15	0.70	6.03	4.33	4.76	3.51
23	7.52	3.17	15	0.93	4.42	3.76	4.93	2.80

Relationship between β-diversity index and environmental gradient

β-diversity indexes of every forest community are calculated (Table 3). β-diversity indexes of 23 communities are relatively low, and the implication of β-diversity is reflecting the similarity of plant species about any two communities. Thus, the similarity of any two of 23 communities is relatively low. It can be found from Table 3 and Fig. 2 that β-diversity index shows a liner increase with the change of environmental gradient. The reason is

that the two communities in good environmental conditions have high similarity, that is to say, species turnover is low, thus, β-diversity index is high and vice versa.

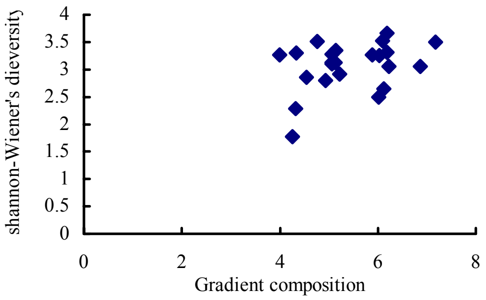

Fig. 1 The relationship between gradient composition and Shannon-wiener's diversity index

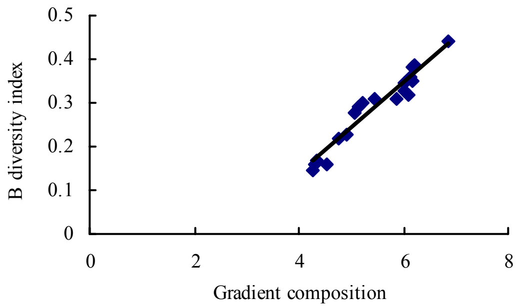

Fig. 2 The relationship between β-diversity index and gradient composition

Table 3. β-diversity index for each forest community

Serial number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
The sequence of community	12	7	19	11	17	22	23	9	20
Environmental gradient composition	3.99	4.26	4.32	4.33	4.54	4.76	4.93	5.07	5.07
β-diversity index	0.107	0.145	0.157	0.168	0.159	0.216	0.228	0.275	0.276
Serial number	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
The sequence of community	13	8	16	21	10	18	6	15	14
Environmental gradient composition	5.13	5.14	5.22	5.45	5.88	6.02	6.03	6.10	6.12
β-diversity index	0.291	0.293	0.302	0.307	0.311	0.326	0.347	0.319	0.357
Serial number	**19**	**20**	**21**	**22**	**23**				
The sequence of community	4	5	1	2	3				
Environmental gradient composition	6.19	6.19	6.22	6.86	7.18				
β-diversity index	0.348	0.382	0.386	0.442					

Conclusion

The species diversity of plant community increases along with the increase of environmental gradient, however, the correlation is not linear. β-diversity index shows a linear increase with the change of environmental gradient.

References

Brown, J.H., and Gibson, A.C. 1983. Biogeography [M]. St. louis: C. V. Mosby Company, USA.

Currie, D.J. and Paquin, V. 1987. Large-scale biogeographical patterns of species richness of trees [J]. Nature, **329**(6): 326–327.

Gaston, K.J. 1996. Biodiversity: a biology of numbers and difference [M]. Oxford: Blackwell.

Kikkawa, J. and Willams, E.E. 1971. Altitude distribution of land birds in new Guinea [J]. Search, **2**(2): 64–69.

Magurran, A.E. 1988. Ecological diversity and its measurement [M]. Princeton, New Jersey, USA, Princeton University Publishing House

Sarkar, S. and Margules, C.R. 2002. Operationalizing biodiversity for conservation planning [J]. Journal of Biosciences, **27**(3): 299–308.

Takacs, D. 1996. The idea of biodiversity: philosophies of paradise [M]. Baltimore: Johns Hopkins University Press.

Terborg, J. 1977. Bird species diversity on an Andean elevational gradient [J]. Ecology, **58**(4): 1007–1019.

Wang Qinggui. 2006. The study on the diversity of forest plants in eastern mountain area of Heilongjiang Province [M]. Harbin: Heilongjiang People Publishing House. (in Chinese)

Whittaker, R.H. 1960. Vegetation of the Siskitou Mountain [J]. Ecol. Moneg, **30**(3): 279–338.

Wilson, E.O. 1992. The diversity of life [M]. Cambridge: Belknap Press.

World Conservation Union. 1980. World conservation strategy: living resource conservation for sustainable development gland: IUCN-UNEP-WWF, Montreal, CAN.